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(54) Abstract Title: **Pipe formability evaluation for expandable tubulars**

(57) A method of testing a tubular member and selecting tubular members for suitability for expansion by subjecting a representative sample the tubular member to axial loading, stretching at least a portion of the tubular member through elastic deformation, plastic yield and to ultimate yield, and based upon changes in length and area calculating an expandability coefficient indicative of expandability of the tubular members and selecting tubular members with relatively high coefficients indicative of good expandability.
The claims are many and varied and relate to inter alia the composition of steel alloy from which the tubular members are formed.

*Fig. 1*

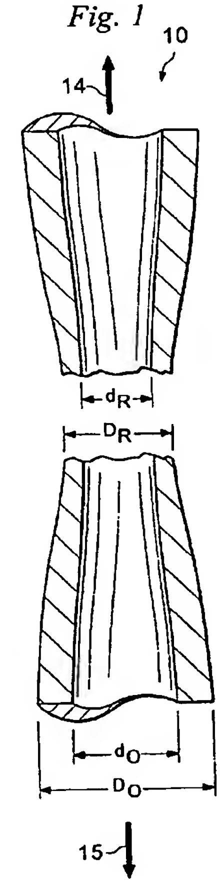


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*Fig. 1*

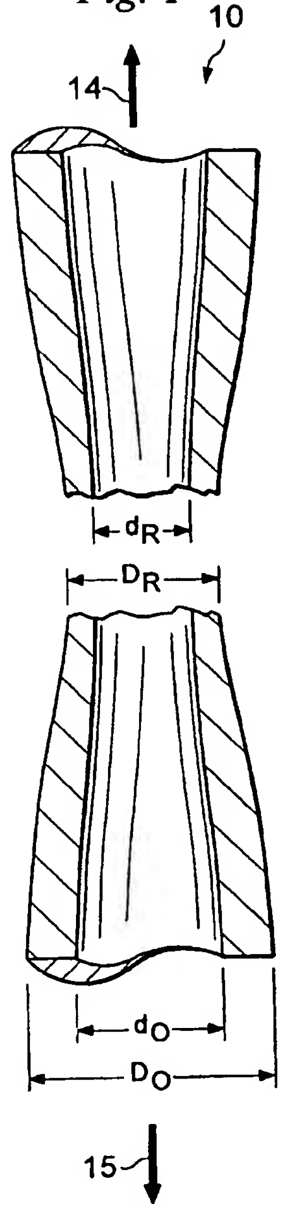


Fig. 2

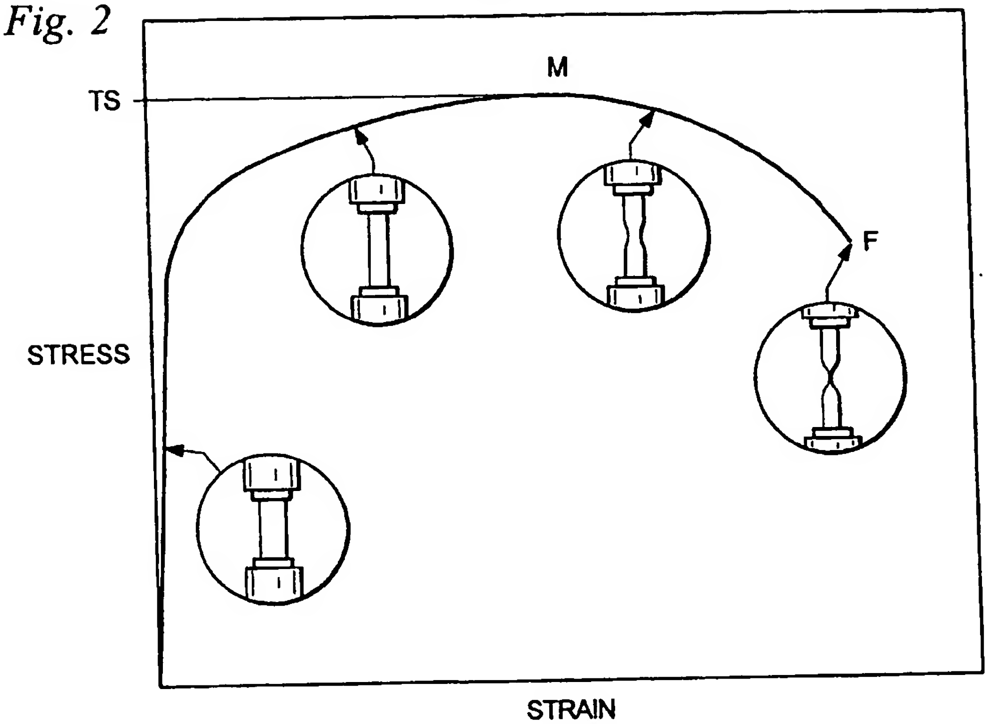
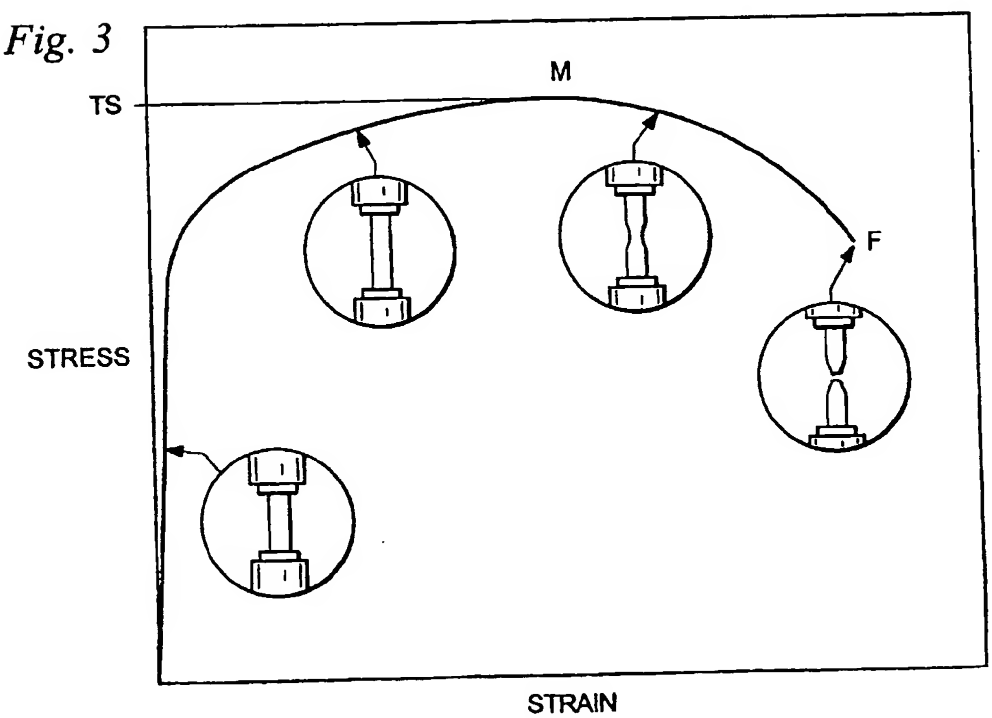



Fig. 3



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**PIPE FORMABILITY EVALUATION FOR EXPANDABLE TUBULARS**

**Cross Reference To Related Applications**

**[001]** The present application is the National Stage patent application for PCT patent application serial number PCT/US2003/025667, attorney docket number 25791.118.02, filed on 8/18/2003, which claimed the benefit of the filing dates of (1) U.S. provisional patent application serial no. 60/412,653, attorney docket no 25791.118, filed on 9/20/2002, the disclosures of which are incorporated herein by reference.

**[002]** The present application is related to the following: (1) U.S. patent application serial no. 09/454,139, attorney docket no. 25791.03.02, filed on 12/3/1999, (2) U.S. patent application serial no. 09/510,913, attorney docket no. 25791.7.02, filed on 2/23/2000, (3) U.S. patent application serial no. 09/502,350, attorney docket no. 25791.8.02, filed on 2/10/2000, (4) U.S. patent no. 6,328,113, (5) U.S. patent application serial no. 09/523,460, attorney docket no. 25791.11.02, filed on 3/10/2000, (6) U.S. patent application serial no. 09/512,895, attorney docket no. 25791.12.02, filed on 2/24/2000, (7) U.S. patent application serial no. 09/511,941, attorney docket no. 25791.16.02, filed on 2/24/2000, (8) U.S. patent application serial no. 09/588,946, attorney docket no. 25791.17.02, filed on 6/7/2000, (9) U.S. patent application serial no. 09/559,122, attorney docket no. 25791.23.02, filed on 4/26/2000, (10) PCT patent application serial no. PCT/US00/18635, attorney docket no. 25791.25.02, filed on 7/9/2000, (11) U.S. provisional patent application serial no. 60/162,671, attorney docket no. 25791.27, filed on 11/1/1999, (12) U.S. provisional patent application serial no. 60/154,047, attorney docket no. 25791.29, filed on 9/16/1999, (13) U.S. provisional patent application serial no. 60/159,082, attorney docket no. 25791.34, filed on 10/12/1999, (14) U.S. provisional patent application serial no. 60/159,039, attorney docket no. 25791.36, filed on 10/12/1999, (15) U.S. provisional patent application serial no. 60/159,033, attorney docket no. 25791.37, filed on 10/12/1999, (16) U.S. provisional patent application serial no. 60/212,359, attorney docket no. 25791.38, filed on 6/19/2000, (17) U.S. provisional patent application serial no. 60/165,228, attorney docket no. 25791.39, filed on 11/12/1999, (18) U.S. provisional patent application serial no. 60/221,443, attorney docket no. 25791.45, filed on 7/28/2000, (19) U.S. provisional patent application serial no. 60/221,645, attorney docket no. 25791.46, filed on 7/28/2000, (20) U.S. provisional patent application serial no. 60/233,638, attorney docket no. 25791.47, filed on 9/18/2000, (21) U.S. provisional patent application serial no. 60/237,334, attorney docket no. 25791.48, filed on 10/2/2000, (22) U.S. provisional patent application serial no. 60/270,007, attorney docket no. 25791.50, filed on 2/20/2001, (23) U.S. provisional patent application serial no. 60/262,434, attorney docket no. 25791.51, filed on 1/17/2001, (24) U.S. provisional patent application serial no. 60/259,486, attorney docket no.

25791.52, filed on 1/3/2001, (25) U.S. provisional patent application serial no. 60/303,740, attorney docket no. 25791.61, filed on 7/6/2001, (26) U.S. provisional patent application serial no. 60/313,453, attorney docket no. 25791.59, filed on 8/20/2001, (27) U.S. provisional patent application serial no. 60/317,985, attorney docket no. 25791.67, filed on 9/6/2001, (28) U.S. provisional patent application serial no. 60/3318,386, attorney docket no. 25791.67.02, filed on 9/10/2001, (29) U.S. utility patent application serial no. 09/969,922, attorney docket no. 25791.69, filed on 10/3/2001, (30) U.S. utility patent application serial no. 10/016,467, attorney docket no. 25791.70, filed on 12/10/2001, (31) U.S. provisional patent application serial no. 60/343,674, attorney docket no. 25791.68, filed on 12/27/2001, (32) U.S. provisional patent application serial no. 60/346,309, attorney docket no 25791.92, filed on 1/7/2002, (33) U.S. provisional patent application serial no. 60/372,048, attorney docket no. 25791.93, filed on 4/12/2002, (34) U.S. provisional patent application serial no. 60/380,147, attorney docket no. 25791.104, filed on 5/6/2002, (35) U.S. provisional patent application serial no. 60/387,486, attorney docket no. 25791.107, filed on 6/10/2002, (36) U.S. provisional patent application serial no. 60/387,961, attorney docket no. 25791.108, filed on 6/12/2002, (37) U.S. provisional patent application serial no. 60/394,703, attorney docket no. 25791.90, filed on 6/26/2002, (38) U.S. provisional patent application serial no. 60/397,284, attorney docket no. 25791.106, filed on 7/19/2002, (39) U.S. provisional patent application serial no. 60/398,061, attorney docket no. 25791.110, filed on 7/24/2002, (40) U.S. provisional patent application serial no, 60/405,610, attorney docket no. 25791.119, filed on 8/23/2002, (41) U.S. provisional patent application serial no. 60/405,394, attorney docket no. 25791.120, filed on 8/23/2002, (42) U.S. provisional patent application serial no. 60/412,542, attorney docket no. 25791.102, filed on 9/20/2002, (43) U.S. provisional patent application serial no. 60/412,487, attorney docket no. 25791.112, filed on 9/20/2002, (44) U.S. provisional patent application serial no. 60/412,488, attorney docket no. 25791.114, filed on 9/20/2002, (45) U.S. provisional patent application serial no. 60/412,177, attorney docket no. 25791.117, filed on 9/20/2002, (46) U.S. provisional patent application serial no. 60/412,653, attorney docket no. 25791.118, filed on 9/20/2002, (47) U.S. provisional patent application serial no. 60/412,544, attorney docket no. 25791.121, filed on 9/20/2002, (48) U.S. provisional patent application serial no. 60/412,196, attorney docket no. 25791.127, filed on 9/20/2002, (49) U.S. provisional patent application serial no. 60/412,187, attorney docket no. 25791.128, filed on 9/20/2002, and (50) U.S. provisional patent application serial no. 60/412,371, attorney docket no. 25791.129, filed on 9/20/2002, the disclosures of which are incorporated herein by reference.

[003] The present application is related to each of the following: (1) U.S. utility patent application serial number _________, attorney docket number 25791.121.___, filed on _________; and (2) U.S.

utility patent application serial number _________, attorney docket number 25791.129.___, filed on _________.

## Background of the Invention

[004] The present invention relates generally to tubular steel well casing and more particularly to an expansion mandrel which reduces stress during expansion of the casing.

[005] Solid tubular casing of substantial length is used as a borehole liner in downhole drilling. The casing is comprised of end-to-end interconnected segments of steel tubing to protect against possible collapse of the borehole and to optimize well flow. The tubing often reaches substantial depths and endures substantial pressures.

[006] It is present practice to expand the steel tubing downhole by using a mandrel. This is a cold-working process which presents substantial mechanical challenges. This technology is known as solid expandable tubular (SET) technology. This cold-working process deforms the steel without any additional heat beyond what is present in the downhole environment.

[007] It is present practice to expand the steel tubing downhole by using a mandrel. This is a cold-working process which presents substantial mechanical challenges. This technology is known as solid expandable tubular (SET) technology. This cold-working process deforms the steel without any additional heat beyond what is present in the downhole environment.

[008] An expansion cone, or mandrel, is used to permanently mechanically deform the pipe. The cone is moved through the tubing by a differential hydraulic pressure across the cone itself, and/or by a direct mechanical pull or push force. The differential pressure is pumped through an inner-string connected to the cone, and the mechanical force is applied by either raising or lowering the inner string.

[009] Progress of the cone through the tubing deforms the steel beyond its elastic limit into the plastic region, while keeping stresses below ultimate yield. Expansions greater than 20%, based on pipe ID, have been accomplished. However, most applications using 4 1/4 - 13 3/8 inch tubing have required expansions less than 20%. The ID of the pipe expands to the same ID of the expansion mandrel, which is a function of expansion mandrel OD. Contact between cylindrical mandrel and pipe ID during expansion leads to significant forces due to friction. It would be beneficial to provide method for testing tubular members for suitability for the expansion process. It would also be beneficial to provide a method for selecting tubing or tubular members well suited for expansion.

## Summary Of The Invention

[0010] According to one aspect of the present invention, a method of testing a tubular member for suitability for expansion is provided using an expandability coefficient determined pursuant to a stress-strain test of a tubular member using axial loading.

[0011] According to another aspect of the present invention, a tubular member is selected for suitability for expansion on a basis comprising use of an expandability coefficient determined pursuant to a stress-strain test of a tubular member using axial loading.

[0012] According to another aspect of the present invention, a method of testing a tubular member for suitability for expansion is provided using an expandability coefficient determined pursuant to a stress-strain test using axial loading comprising calculation of plastic strain ratio for obtaining the expansion coefficient pursuant to test results and using the formula:

$$f = \frac{\ln \frac{b_o}{b_k}}{\ln \frac{L_k b_k}{l_o b_o}} \qquad \text{Equation 1}$$

where,

$f$ - expandability coefficient

bo & bk - initial and final tube area (inch^2)

Lo & Lk - initial and final tube length (inch)

b = (D^2-d^2)/4 - cross section tube area.

[0013] According to another aspect of the present invention, a tubular member is selected for suitability for expansion on a basis comprising use of an expandability coefficient determined pursuant to a stress-strain test using axial loading comprising calculation of plastic strain ratio for obtaining the expansion coefficient pursuant to test results and using the formula:

$$f = \frac{\ln \frac{b_o}{b_k}}{\ln \frac{L_k b_k}{l_o b_o}} \qquad \text{Equation 1}$$

where,

$f$ - expandability coefficient

bo & bk - initial and final tube area (inch^2)

Lo & Lk - initial and final tube length (Inch)

b = (D^2-d^2)/4 - cross section tube area.

[0014] According to another aspect of the present invention, a tubular member is selected for suitability for expansion on a basis comprising use of an expandability coefficient determined pursuant to a stress-strain test using axial loading and one or more physical properties of the tubular member selected from stress-strain properties in one or more directional orientations of the material,

Charpy V-notch impact value in one or more directional orientations of the material, stress rupture burst strength, stress rupture collapse strength, strain-hardening exponent(n-value), hardness and yield strength.

[0015] According to another aspect of the present invention, a method for manufacturing an expandable member used to complete a structure by radially expanding and plastically deforming the expandable member is provided that includes forming the expandable member from a steel alloy comprising a charpy energy of at least about 90 ft-lbs.

[001] According to another aspect of the present invention, an expandable member for use in completing a structure by radially expanding and plastically deforming the expandable member is provided that includes a steel alloy comprising a charpy energy of at least about 90 ft-lbs.

[002] According to another aspect of the present invention, a structural completion positioned within a structure is provided that includes one or more radially expanded and plastically deformed expandable members positioned within the structure; wherein one or more of the radially expanded and plastically deformed expandable members are fabricated from a steel alloy comprising a charpy energy of at least about 90 ft-lbs.

[003] According to another aspect of the present invention, a method for manufacturing an expandable member used to complete a structure by radially expanding and plastically deforming the expandable member is provided that includes forming the expandable member from a steel alloy comprising a weight percentage of carbon of less than about 0.08%.

[004] According to another aspect of the present invention, an expandable member for use in completing a wellbore by radially expanding and plastically deforming the expandable member at a downhole location in the wellbore is provided that includes a steel alloy comprising a weight percentage of carbon of less than about 0.08%.

[005] According to another aspect of the present invention, a structural completion is provided that includes one or more radially expanded and plastically deformed expandable members positioned within the wellbore; wherein one or more of the radially expanded and plastically deformed expandable members are fabricated from a steel alloy comprising a weight percentage of carbon of less than about 0.08%.

[006] According to another aspect of the present invention, a method for manufacturing an expandable member used to complete a structure by radially expanding and plastically deforming the expandable member is provided that includes forming the expandable member from a steel alloy comprising a weight percentage of carbon of less than about 0.20% and a charpy V-notch impact toughness of at least about 6 joules.

[007] According to another aspect of the present invention, an expandable member for use in completing a structure by radially expanding and plastically deforming the expandable member

is provided that includes a steel alloy comprising a weight percentage of carbon of less than about 0.20% and a charpy V-notch impact toughness of at least about 6 joules.

**[008]** According to another aspect of the present invention, a structural completion is provided that includes one or more radially expanded and plastically deformed expandable members; wherein one or more of the radially expanded and plastically deformed expandable members are fabricated from a steel alloy comprising a weight percentage of carbon of less than about 0.20% and a charpy V-notch impact toughness of at least about 6 joules.

**[009]** According to another aspect of the present invention, a method for manufacturing an expandable member used to complete a structure by radially expanding and plastically deforming the expandable member is provided that includes forming the expandable member from a steel alloy comprising the following ranges of weight percentages: C, from about 0.002 to about 0.08; Si, from about 0.009 to about 0.30; Mn, from about 0.10 to about 1.92; P, from about 0.004 to about 0.07; S, from about 0.0008 to about 0.006; Al, up to about 0.04; N, up to about 0.01; Cu, up to about 0.3; Cr, up to about 0.5; Ni, up to about 18; Nb, up to about 0.12; Ti, up to about 0.6; Co, up to about 9; and Mo, up to about 5.

**[0010]** According to another aspect of the present invention, an expandable member for use in completing a structure by radially expanding and plastically deforming the expandable member is provided that includes a steel alloy comprising the following ranges of weight percentages: C, from about 0.002 to about 0.08; Si, from about 0.009 to about 0.30; Mn, from about 0.10 to about 1.92; P, from about 0.004 to about 0.07; S, from about 0.0008 to about 0.006; Al, up to about 0.04; N, up to about 0.01; Cu, up to about 0.3; Cr, up to about 0.5; Ni, up to about 18; Nb, up to about 0.12; Ti, up to about 0.6; Co, up to about 9; and Mo, up to about 5.

**[0011]** According to another aspect of the present invention, a structural completion is provided that includes one or more radially expanded and plastically deformed expandable members; wherein one or more of the radially expanded and plastically deformed expandable members are fabricated from a steel alloy comprising the following ranges of weight percentages: C, from about 0.002 to about 0.08; Si, from about 0.009 to about 0.30; Mn, from about 0.10 to about 1.92; P, from about 0.004 to about 0.07; S, from about 0.0008 to about 0.006; Al, up to about 0.04; N, up to about 0.01; Cu, up to about 0.3; Cr, up to about 0.5; Ni, up to about 18; Nb, up to about 0.12; Ti, up to about 0.6; Co, up to about 9; and Mo, up to about 5.

**[0012]** According to another aspect of the present invention, a method for manufacturing an expandable tubular member used to complete a structure by radially expanding and plastically deforming the expandable member is provided that includes forming the expandable tubular member with a ratio of the of an outside diameter of the expandable tubular member to a wall thickness of the expandable tubular member ranging from about 12 to 22.

[0013] According to another aspect of the present invention, an expandable member for use in completing a structure by radially expanding and plastically deforming the expandable member is provided that includes an expandable tubular member with a ratio of the of an outside diameter of the expandable tubular member to a wall thickness of the expandable tubular member ranging from about 12 to 22.

[0014] According to another aspect of the present invention, a structural completion is provided that includes one or more radially expanded and plastically deformed expandable members positioned within the structure; wherein one or more of the radially expanded and plastically deformed expandable members are fabricated from an expandable tubular member with a ratio of the of an outside diameter of the expandable tubular member to a wall thickness of the expandable tubular member ranging from about 12 to 22.

[0015] According to another aspect of the present invention, a method of constructing a structure is provided that includes radially expanding and plastically deforming an expandable member; wherein an outer portion of the wall thickness of the radially expanded and plastically deformed expandable member comprises tensile residual stresses.

[0016] According to another aspect of the present invention, a structural completion is provided that includes one or more radially expanded and plastically deformed expandable members; wherein an outer portion of the wall thickness of one or more of the radially expanded and plastically deformed expandable members comprises tensile residual stresses.

[0017] According to another aspect of the present invention, a method of constructing a structure using an expandable tubular member is provided that includes strain aging the expandable member; and then radially expanding and plastically deforming the expandable member.

[0018] According to another aspect of the present invention, a method for manufacturing a tubular member used to complete a wellbore by radially expanding the tubular member at a downhole location in the wellbore comprising: forming a steel alloy comprising a concentration of carbon between approximately 0.002% and 0.08% by weight of the steel alloy.

## Brief Description of the Drawings

[0016] Fig. 1 depicts in a schematic fragmentary cross-sectional view along a plane along and through the central axis of a tubular member that is tested to failure with axial opposed forces.

[0017] Fig. 2 is a stress-strain curve representing values for stress and strain that may be plotted for solid specimen sample.

[0018] Fig. 3. is a schematically depiction of a stress strain curve representing values from a test on a tubular member according to an illustrative example of one aspect of the invention.

## Detailed Description of the Illustrative Embodiments

[0019] One of the problems of the pipe material selection for expandable tubular application is an apparent contradiction or inconsistency between strength and elongation. To increase burst and collapse strength, material with higher yield strength is used. The higher yield strength generally corresponds to a decrease in the fracture toughness and correspondingly limits the extent of achievable expansion.

[0020] It is desirable to select the steel material for the tubing by balancing steel strength with amount absorbed energy measure by Charpy testing. Generally these tests are done on samples cut from tubular members. It has been found to be beneficial to cut directional samples both longitudinally oriented (aligned with the axis) and circumferentially oriented (generally perpendicular to the axis). This method of selecting samples is beneficial when both directional orientations are used yet does not completely evaluate possible and characteristic anisotropy throughout a tubular member. Moreover, for small diameter tubing samples representative of the circumferential direction may be difficult and sometimes impossible to obtain because of the significant curvature of the tubing.

[0021] To further facilitate evaluation of a tubular member for suitability for expansion it has been found beneficial according to one aspect of the invention to consider the plastic strain ratio. One such ratio is called a Lankford value (or r-value) which is the ratio of the strains occurring in the width and thickness directions measured in a single tension test. The plastic strain ratio (r or Lankford - value) with a value of greater than 1.0 is found to be more resistant to thinning and better suited to tubular expansion. Such a Lankford value is found to be a measure of plastic anisotropy. The Lankford value (r) may be calculate by the Equation 2 below:

$$r = \frac{ln\frac{b_o}{b_k}}{ln\frac{L_k b_k}{l_o b_o}} \qquad \text{Equation 2}$$

where,

$r$ - normal anisotropy coefficient

bo & bk - initial and final width

Lo & Lk - initial and final length

[0022] However, it is time consuming and labor intensive for this parameter to be measured using samples cut from real parts such as from the tubular members. The tubular members will have anisotropic characteristics due to crystallographic or "grain " orientation and mechanically induced differences such as impurities, inclusions, and voids, requiring multiple samples for reliably complete

information. Moreover, with individual samples, only local characteristics are determined and the complete anisotropy of the tubular member may not be determinable. Further some of the tubular members have small diameters so that cutting samples oriented in a circumferential direction is not always possible. Information regarding the characteristics in the circumferential direction has been found to be important because the plastic deformation during expansion of the tubular members occurs to a very large extent in the circumferential direction,

[0023] One aspect of the present invention comprises the development of a solution for anisotropy evaluation, including a kind of plastic strain ratio similar to the Lankford parameter that is measured using real tubular members subjected to axial loading.

[0024] Fig. 1 depicts in a schematic fragmentary cross-sectional view along a plane along and through the axis 12 of a tubular member 10 that is tested with axial opposed forces 14 and 15. The tubular member 10 is axially stretched beyond the elastic limit, through yielding and to ultimate yield or fracture. Measurements of the force and the OD and ID during the process produce test data that can be used in the formula below to produce an expandability coefficient "*f*" as set forth in Equation 1 above. Alternatively a coefficient called a formability anisotropy coefficient *F(r)* that is function of the normal anisotropy Lankford coefficient *r* may be determined as in Equation 3 below:

$$F(r) = \frac{\ln \frac{b_o}{b_k}}{\ln \frac{L_k b_k}{l_o b_o}} \qquad \text{Equation 3}$$

*F(r)* - formability anisotropy coefficient

bo & bk - initial and final tube area (inch^2)

Lo & Lk - initial and final tube length (inch)

b = (D^2-d^2)/4- cross section tube area.

[0025] In either circumstance *f* or *F(r)* the use of this testing method for an entire tubular member provides useful information including anisotropic characteristics or anisotropy of the tubular member for selecting or producing beneficial tubular members for down hole expansion, similar to the use of the Lankford value for a sheet material.

[0026] Just as values for stress and strain may be plotted for solid specimen samples, as schematically depicted in Fig 2, the values for conducting a test on the tubular member may also be plotted, as depicted in Fig 3. On this basis the expansion coefficient *f* (or the formability coefficient *F(r)*) may be determined. It will be the best to measure distribution (Tensile-elongation) in longitudinal and circumferential directions simultaneously.

[0027] The foregoing expandability coefficient (or formability coefficient) is found to be useful in

predicting good expansion results and may be further useful when used in combination with one or more other properties of a tubular member selected from stress-strain properties in one or more directional orientations of the material, strength & elongation, Charpy V-notch impact value in one or more directional orientations of the material, stress burst rupture, stress collapse rupture, yield strength, ductility, toughness, and strain-hardening exponent (n - value), and hardness.

[0019] In an exemplary embodiment, a tribological system is used to reduce friction and thereby minimize the expansion forces required during the radial expansion and plastic deformation of the tubular members that includes one or more of the following: (1) a tubular tribology system; (2) a drilling mud tribology system; (3) a lubrication tribology system; and (4) an expansion device tribology system.

[0020] In an exemplary embodiment, the tubular tribology system includes the application of coatings of lubricant to the interior surface of the tubular members.

[0021] In an exemplary embodiment, the drilling mud tribology system includes the addition of lubricating additives to the drilling mud.

[0022] In an exemplary embodiment, the lubrication tribology system includes the use of lubricating greases, self-lubricating expansion devices, automated injection/delivery of lubricating greases into the interface between an expansion device and the tubular members, surfaces within the interface between the expansion device and the expandable tubular member that are self-lubricating, surfaces within the interface between the expansion device and the expandable tubular member that are textured, self-lubricating surfaces within the interface between the expansion device and the expandable tubular member that include diamond and/or ceramic inserts, thermosprayed coatings, fluoropolymer coatings, PVD films, and/or CVD films.

[0023] In an exemplary embodiment, the tubular members include one or more of the following characteristics: high burst and collapse, the ability to be radially expanded more than about 40%, high fracture toughness, defect tolerance, strain recovery @ 150 F, good bending fatigue, optimal residual stresses, and corrosion resistance to $H_2S$ in order to provide optimal characteristics during and after radial expansion and plastic deformation.

[0024] In an exemplary embodiment, the tubular members are fabricated from a steel alloy having a charpy energy of at least about 90 ft-lbs in order to provided enhanced characteristics during and after radial expansion and plastic deformation of the expandable tubular member.

[0025] In an exemplary embodiment, the tubular members are fabricated from a steel alloy having a weight percentage of carbon of less than about 0.08% in order to provide enhanced characteristics during and after radial expansion and plastic deformation of the tubular members.

[0026] In an exemplary embodiment, the tubular members are fabricated from a steel alloy having reduced sulfur content in order to minimize hydrogen induced cracking.

[0027] In an exemplary embodiment, the tubular members are fabricated from a steel alloy having a weight percentage of carbon of less than about 0.20 % and a charpy-V-notch impact toughness of at least about 6 joules in order to provide enhanced characteristics during and after radial expansion and plastic deformation of the tubular members.

[0028] In an exemplary embodiment, the tubular members are fabricated from a steel alloy having a low weight percentage of carbon in order to enhance toughness, ductility, weldability, shelf energy, and hydrogen induced cracking resistance.

[0029] In several exemplary embodiments, the tubular members are fabricated from a steel alloy having the following percentage compositions in order to provide enhanced characteristics during and after radial expansion and plastic deformation of the tubular members:

| | C | Si | Mn | P | S | Al | N | Cu | Cr | Ni | Nb | Ti | Co | Mo |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| EXAMPLE A | 0.030 | 0.22 | 1.74 | 0.005 | 0.0005 | 0.028 | 0.0037 | 0.30 | 0.26 | 0.15 | 0.095 | 0.014 | 0.0034 | |
| EXAMPLE B MIN | 0.020 | 0 23 | 1.70 | 0.004 | 0.0005 | 0.026 | 0.0030 | 0.27 | 0.26 | 0.16 | 0.096 | 0.012 | 0.0021 | |
| EXAMPLE B MAX | 0.032 | 0.26 | 1.92 | 0.009 | 0.0010 | 0.035 | 0.0047 | 0.32 | 0.29 | 0.18 | 0.120 | 0.016 | 0.0050 | |
| EXAMPLE C | 0.028 | 0.24 | 1.77 | 0.007 | 0.0008 | 0.030 | 0.0035 | 0.29 | 0.27 | 0.17 | 0.101 | 0.014 | 0.0028 | 0.0020 |
| EXAMPLE D | 0.08 | 0.30 | 0.5 | 0.07 | 0.005 | | 0.010 | 0.10 | 0.50 | 0.10 | | | | |
| EXAMPLE E | 0.0028 | 0.009 | 0.17 | 0.011 | 0.006 | 0.027 | 0.0029 | | 0.029 | 0.014 | 0.035 | 0.007 | | |
| EXAMPLE F | 0 03 | 0.1 | 0.1 | 0.015 | 0.005 | | | | | 18.0 | | 0.6 | 9 | 5 |
| EXAMPLE G | 0.002 | 0.01 | 0.15 | 0.07 | 0.005 | 0.04 | 0.0025 | | | | 0.015 | 0.010 | | |

[0030] In an exemplary embodiment, the ratio of the outside diameter D of the tubular members to the wall thickness t of the tubular members range from about 12 to 22 in order to enhance the collapse strength of the radially expanded and plastically deformed tubular members.

[0031] In an exemplary embodiment, the outer portion of the wall thickness of the radially expanded and plastically deformed tubular members includes tensile residual stresses in order to enhance the collapse strength following radial expansion and plastic deformation.

[0032] In several exemplary experimental embodiments, reducing residual stresses in samples of the tubular members prior to radial expansion and plastic deformation increased the collapse strength of the radially expanded and plastically deformed tubular members.

[0033] In several exemplary experimental embodiments, the collapse strength of radially expanded and plastically deformed samples of the tubulars were determined on an as-received basis, after strain aging at 250 F for 5 hours to reduce residual stresses, and after strain aging at 350 F for 14 days to reduce residual stresses as follows:

| Tubular Sample | Collapse Strength After 10% Radial Expansion |
| --- | --- |
| Tubular Sample 1 – as received from manufacturer | 4000 psi |
| Tubular Sample 1 – strain aged at 250 F for 5 hours to reduce residual stresses | 4800 psi |
| Tubular Sample 1 – strain aged at 350 F for 14 days to reduce residual stresses | 5000 psi |

**[0034]** As indicated by the above table, reducing residual stresses in the tubular members, prior to radial expansion and plastic deformation, significantly increased the resulting collapse strength – post expansion.

**[0035]** A method for manufacturing an expandable member used to complete a structure by radially expanding and plastically deforming the expandable member has been described that includes forming the expandable member from a steel alloy comprising a charpy energy of at least about 90 ft-lbs.

**[0036]** An expandable member for use in completing a structure by radially expanding and plastically deforming the expandable member has been described that includes a steel alloy comprising a charpy energy of at least about 90 ft-lbs.

**[0037]** A structural completion positioned within a structure has been described that includes one or more radially expanded and plastically deformed expandable members positioned within the structure; wherein one or more of the radially expanded and plastically deformed expandable members are fabricated from a steel alloy comprising a charpy energy of at least about 90 ft-lbs.

**[0038]** A method for manufacturing an expandable member used to complete a structure by radially expanding and plastically deforming the expandable member has been described that includes forming the expandable member from a steel alloy comprising a weight percentage of carbon of less than about 0.08%.

**[0039]** An expandable member for use in completing a wellbore by radially expanding and plastically deforming the expandable member at a downhole location in the wellbore has been described that includes a steel alloy comprising a weight percentage of carbon of less than about 0.08%.

**[0040]** A structural completion has been described that includes one or more radially expanded and plastically deformed expandable members positioned within the wellbore; wherein one or more of the radially expanded and plastically deformed expandable members are fabricated from a steel alloy comprising a weight percentage of carbon of less than about 0.08%.

[0041] A method for manufacturing an expandable member used to complete a structure by radially expanding and plastically deforming the expandable member has been described that includes forming the expandable member from a steel alloy comprising a weight percentage of carbon of less than about 0.20% and a charpy V-notch impact toughness of at least about 6 joules.

[0042] An expandable member for use in completing a structure by radially expanding and plastically deforming the expandable member has been described that includes a steel alloy comprising a weight percentage of carbon of less than about 0.20% and a charpy V-notch impact toughness of at least about 6 joules.

[0043] A structural completion has been described that includes one or more radially expanded and plastically deformed expandable members; wherein one or more of the radially expanded and plastically deformed expandable members are fabricated from a steel alloy comprising a weight percentage of carbon of less than about 0.20% and a charpy V-notch impact toughness of at least about 6 joules.

[0044] A method for manufacturing an expandable member used to complete a structure by radially expanding and plastically deforming the expandable member has been described that includes forming the expandable member from a steel alloy comprising the following ranges of weight percentages: C, from about 0.002 to about 0.08; Si, from about 0.009 to about 0.30; Mn, from about 0.10 to about 1.92; P, from about 0.004 to about 0.07; S, from about 0.0008 to about 0.006; Al, up to about 0.04; N, up to about 0.01; Cu, up to about 0.3; Cr, up to about 0.5; Ni, up to about 18; Nb, up to about 0.12; Ti, up to about 0.6; Co, up to about 9; and Mo, up to about 5.

[0045] An expandable member for use in completing a structure by radially expanding and plastically deforming the expandable member has been described that includes a steel alloy comprising the following ranges of weight percentages: C, from about 0.002 to about 0.08; Si, from about 0.009 to about 0.30; Mn, from about 0.10 to about 1.92; P, from about 0.004 to about 0.07; S, from about 0.0008 to about 0.006; Al, up to about 0.04; N, up to about 0.01; Cu, up to about 0.3; Cr, up to about 0.5; Ni, up to about 18; Nb, up to about 0.12; Ti, up to about 0.6; Co, up to about 9; and Mo, up to about 5.

[0046] A structural completion has been described that includes one or more radially expanded and plastically deformed expandable members; wherein one or more of the radially expanded and plastically deformed expandable members are fabricated from a steel alloy comprising the following ranges of weight percentages: C, from about 0.002 to about 0.08; Si, from about 0.009 to about 0.30; Mn, from about 0.10 to about 1.92; P, from about 0.004 to about 0.07; S, from about 0.0008 to about 0.006; Al, up to about 0.04; N, up to about 0.01; Cu, up to about 0.3; Cr,

up to about 0.5; Ni, up to about 18; Nb, up to about 0.12; Ti, up to about 0.6; Co, up to about 9; and Mo, up to about 5.

[0047] A method for manufacturing an expandable tubular member used to complete a structure by radially expanding and plastically deforming the expandable member has been described that includes forming the expandable tubular member with a ratio of the of an outside diameter of the expandable tubular member to a wall thickness of the expandable tubular member ranging from about 12 to 22.

[0048] An expandable member for use in completing a structure by radially expanding and plastically deforming the expandable member has been described that includes an expandable tubular member with a ratio of the of an outside diameter of the expandable tubular member to a wall thickness of the expandable tubular member ranging from about 12 to 22.

[0049] A structural completion has been described that includes one or more radially expanded and plastically deformed expandable members positioned within the structure; wherein one or more of the radially expanded and plastically deformed expandable members are fabricated from an expandable tubular member with a ratio of the of an outside diameter of the expandable tubular member to a wall thickness of the expandable tubular member ranging from about 12 to 22.

[0050] A method of constructing a structure has been described that includes radially expanding and plastically deforming an expandable member; wherein an outer portion of the wall thickness of the radially expanded and plastically deformed expandable member comprises tensile residual stresses.

[0051] A structural completion has been described that includes one or more radially expanded and plastically deformed expandable members; wherein an outer portion of the wall thickness of one or more of the radially expanded and plastically deformed expandable members comprises tensile residual stresses.

[0052] A method of constructing a structure using an expandable tubular member has been described that includes strain aging the expandable member; and then radially expanding and plastically deforming the expandable member.

[0053] A method for manufacturing a tubular member used to complete a wellbore by radially expanding the tubular member at a downhole location in the wellbore has been described that includes forming a steel alloy comprising a concentration of carbon between approximately 0.002% and 0.08% by weight of the steel alloy.

[0054] It is understood that variations may be made to the foregoing without departing from the spirit of the invention. For example, the teachings of the present disclosure may be used to form and/or repair a wellbore casing, a pipeline, or a structural support. Furthermore, the various

teachings of the present disclosure may combined, in whole or in part, with various of the teachings of the present disclosure.

[0028] Although illustrative embodiments of the invention have been shown and described, a wide range of modification, changes and substitution is contemplated in the foregoing disclosure. In some instances, some features of the present invention may be employed without a corresponding use of the other features. Accordingly, it is appropriate that the appended claims be construed broadly and in a manner consistent with the scope of the invention.

What is claimed is:

1. A method of testing a tubular member for suitability for radial expansion and plastic deformation comprising: subjecting at least a portion of the tubular member to axial loading, stretching at least a portion of the tubular member through the elastic deformation, plastic yield and to ultimate yield, and calculating an expandability coefficient *f*.

2. The method of claim 1, wherein subjecting the at least a portion of the tubular member to axial loading comprises subjecting the entire tubular member to axial loading.

3. The method of claim 1, wherein the step of calculating an expandability coefficient comprises calculating the expandability coefficient using the following formula:

$$f = \frac{\ln\frac{b_o}{b_k}}{\ln\frac{L_k b_k}{l_o b_o}} \qquad \text{[Equation 1]}$$

where,

$f$ - expandability coefficient;

bo & bk - initial and final tube cross-sectional area (inch$^2$);

Lo & Lk - initial and final tube length (inch);

b = $(D^2-d^2)/4$ - cross section tube area;

D = tube outside diameter; and

d = tube inside diameter.

4. A method of selecting tubular members for suitability for radial expansion and plastic deformation comprising subjecting at least a portion of a representative sample of tubular members to axial loading, stretching at least a portion of the tubular members through the elastic deformation, plastic yield and to ultimate yield, and calculating an expandability coefficient *f*, and choosing such tubular members for which the sample provided a desirable coefficient of expandability above a value of 1.

5. The method of claim 4, wherein subjecting the at least a portion of a representative sample of tubular members to axial loading comprises subjecting the entire length of at least one of the tubular members to axial loading.

6. The method of claim 4, wherein the step of calculating an expandability coefficient comprises calculating the expandability coefficient using the following formula:

$$f = \frac{\ln \frac{b_o}{b_k}}{\ln \frac{L_k b_k}{l_o b_o}} \qquad \text{[Equation 1]}$$

where,

$f$ - expandability coefficient;

bo & bk - initial and final tube cross sectional area (inch$^2$);

Lo & Lk - initial and final tube length (inch);

b = $(D^2-d^2)/4$ - cross section tube area;

D = tube outside diameter; and

d = tube inside diameter.

7. A method of selecting a tubular member for suitability for radial expansion and plastic deformation comprising using an expandability coefficient determined pursuant to a stress-strain test using axial loading in combination with one or more physical properties of the tubular member selected from a group of properties comprising stress-strain properties in one or more directional orientations of the material, Charpy V-notch impact value in one or more directional orientations of the material, stress rupture burst strength, stress rupture collapse strength, yield strength, strain-hardening exponent (n-value), and hardness.

8. A system for testing a tubular member for suitability for radial expansion and plastic deformation comprising:

means for subjecting at least a portion of the tubular member to axial loading,

means for stretching at least a portion of the tubular member through the elastic deformation, plastic yield and to ultimate yield, and

means for calculating an expandability coefficient $f$.

9. The system of claim 8, wherein means for subjecting the at least a portion of the tubular member to axial loading comprises means for subjecting the entire tubular member to axial loading.

10. The system of claim 8, wherein means for calculating an expandability coefficient

comprises calculating the expandability coefficient using the following formula:

$$f = \frac{\ln \frac{b_o}{b_k}}{\ln \frac{L_k b_k}{l_o b_o}}$$

where,

$f$ - expandability coefficient;

bo & bk - initial and final tube cross sectional area (inch$^2$);

Lo & Lk - initial and final tube length (inch);

b = $(D^2 - d^2)/4$ - cross section tube area;

D = tube outside diameter; and

d = tube inside diameter.

11. A system for selecting tubular members for suitability for radial expansion and plastic deformation comprising:

means for subjecting at least a portion of a representative sample of tubular members to axial loading,

means for stretching at least a portion of the tubular members through the elastic deformation, plastic yield and to ultimate yield, and

means for calculating an expandability coefficient $f$, and choosing such tubular members for which the sample provided a desirable coefficient of expandability above a value of 1.

12. The system of claim 11, wherein means for subjecting the at least a portion of a representative sample of tubular members to axial loading comprises means for subjecting the entire length of at least one of the tubular members to axial loading.

13. The system of claim 11, wherein means for calculating an expandability coefficient comprises means for calculating the expandability coefficient using the following formula:

$$f = \frac{\ln \frac{b_o}{b_k}}{\ln \frac{L_k b_k}{l_o b_o}}$$

where,

$f$ - expandability coefficient;
bo & bk - initial and final tube cross sectional area (inch$^2$);
Lo & Lk - initial and final tube length (inch);
$b = (D^2-d^2)/4$ - cross section tube area;
$D$ = tube outside diameter; and
$d$ = tube inside diameter.

14. A system for selecting a tubular member for suitability for radial expansion and plastic deformation comprising:
means for conducting a stress-strain test on the tubular member;
means for calculating an expandability coefficient determined pursuant to the stress-strain test; and
means for selecting the tubular member as a function of the expandability coefficient and one or more physical properties of the tubular member selected from a group of properties comprising stress-strain properties in one or more directional orientations of the material, Charpy V-notch impact value in one or more directional orientations of the material, stress rupture burst strength, stress rupture collapse strength, yield strength, strain-hardening exponent (n-value), and hardness.

15. The method of claim 1, further comprising:
selecting the tubular member for radial expansion and plastic deformation if the expandability coefficient is greater than or equal to a predetermined value.

16. The method of claim 15, further comprising:
radially expanding and plastically deforming the selected tubular member.

17. The method of claim 4, further comprising:
radially expanding and plastically deforming one or more of the selected tubular members.

18. The method of claim 7, further comprising:
radially expanding and plastically deforming the selected tubular members.

19. A method of selecting tubular members for radial expansion and plastic deformation,

comprising:

characterizing one or more anisotropic characteristics of the tubular members.

20. The method of claim 19, wherein at least one of the anisotropic characteristics comprises a measurement of the plastic anisotropy for the tubular members.

21. A system of selecting tubular members for radial expansion and plastic deformation, comprising:

means for characterizing one or more anisotropic characteristics of the tubular members; and

means for radially expanding and plastically deforming one or more selected tubular members.

22. The system of claim 21, wherein at least one of the anisotropic characteristics comprises a measurement of the plastic anisotropy for the tubular members.

23. The system of claim 21, wherein the selected tubular members comprise a plastic anisotropy measurement equal to a predetermined value.

24. A tubular member, comprising:

a plasticity characteristic that is anisotropic.

25. A system for radially expanding and plastically deforming a tubular member, comprising:

means for selecting tubular members suitable for radial expansion and plastic deformation; and

means for radially expanding and plastically deforming the tubular member.

26. The system of claim 25, wherein tubular members suitable for radial expansion and plastic deformation comprise a plasticity characteristic that is anisotropic.

27. The method of claim 1, further comprising:

selecting a tubular member for radial expansion and plastic deformation as function of the calculated formability coefficient.

28. The method of claim 1, further comprising:

selecting a tubular member for radial expansion and plastic deformation as function of the calculated formability coefficient and one or more of the following:

stress-strain properties in one or more directional orientations, Charpy V-notch impact value in one or more directional orientations, stress rupture burst strength, stress rupture collapse strength, yield strength, strain-hardening exponent (n-value), and hardness.

29. A method of selecting tubular members suitable for radial expansion and plastic deformation, comprising:

selecting a tubular member for radial expansion and plastic deformation as function of formability anisotropy.

30. A method of selecting tubular members suitable for radial expansion and plastic deformation, comprising:

selecting a tubular member for radial expansion and plastic deformation as function of formability anisotropy and one or more of the following:

stress-strain properties in one or more directional orientations, Charpy V-notch impact value in one or more directional orientations, stress rupture burst strength, stress rupture collapse strength, yield strength, strain-hardening exponent (n-value), and hardness.

31. A method of radially expanding and plastically deforming tubular members, comprising:

selecting a tubular member for radial expansion and plastic deformation as function of the formability anisotropy for the tubular member; and

radially expanding and plastically deforming the selected tubular member.

32. A method of radially expanding and plastically deforming tubular members, comprising:

selecting a tubular member for radial expansion and plastic deformation as function of the formability anisotropy for the tubular member and one or more of the following:

stress-strain properties in one or more directional orientations, Charpy V-notch impact value in one or more directional orientations, stress rupture burst strength, stress rupture collapse strength, yield strength, strain-hardening exponent (n-value), and hardness; and

radially expanding and plastically deforming the selected tubular member.

33. A system for radially expanding and plastically deforming tubular members, comprising:
means for selecting a tubular member for radial expansion and plastic deformation as function of
the formability anisotropy for the tubular member; and
means for radially expanding and plastically deforming the selected tubular member.

34. A system for radially expanding and plastically deforming tubular members, comprising:
means for selecting a tubular member for radial expansion and plastic deformation as function of the formability anisotropy for the tubular member and one or more of the following:
stress-strain properties in one or more directional orientations, Charpy V-notch impact value in one or more directional orientations, stress rupture burst strength, stress rupture collapse strength, yield strength, strain-hardening exponent (n-value), and hardness; and
means for radially expanding and plastically deforming the selected tubular member.

35. An apparatus, comprising:
a subterranean formation defining a borehole; and
a radially expanded and plastically deformed tubular member positioned within and coupled to the borehole;
wherein at least a portion of the tubular member comprises a formability characteristic that is anisotropic.

36. A method for manufacturing an expandable member used to complete a structure by radially expanding and plastically deforming the expandable member comprising:
forming the expandable member from a steel alloy comprising a charpy energy of at least about 90 ft-lbs.

37. An expandable member for use in completing a structure by radially expanding and plastically deforming the expandable member, comprising:
a steel alloy comprising a charpy energy of at least about 90 ft-lbs.

38. A structural completion positioned within a structure, comprising:
one or more radially expanded and plastically deformed expandable members positioned within the structure;

wherein one or more of the radially expanded and plastically deformed expandable members are fabricated from a steel alloy comprising a charpy energy of at least about 90 ft-lbs.

39. A method for manufacturing an expandable member used to complete a structure by radially expanding and plastically deforming the expandable member, comprising:

forming the expandable member from a steel alloy comprising a weight percentage of carbon of less than about 0.08%.

40. An expandable member for use in completing a wellbore by radially expanding and plastically deforming the expandable member at a downhole location in the wellbore, comprising:

a steel alloy comprising a weight percentage of carbon of less than about 0.08%.

41. A structural completion, comprising:

one or more radially expanded and plastically deformed expandable members positioned within the wellbore;

wherein one or more of the radially expanded and plastically deformed expandable members are fabricated from a steel alloy comprising a weight percentage of carbon of less than about 0.08%.

42. A method for manufacturing an expandable member used to complete a structure by radially expanding and plastically deforming the expandable member, comprising:

forming the expandable member from a steel alloy comprising a weight percentage of carbon of less than about 0.20% and a charpy V-notch impact toughness of at least about 6 joules.

43. An expandable member for use in completing a structure by radially expanding and plastically deforming the expandable member, comprising:

a steel alloy comprising a weight percentage of carbon of less than about 0.20% and a charpy V-notch impact toughness of at least about 6 joules.

44. A structural completion, comprising:

one or more radially expanded and plastically deformed expandable members;

wherein one or more of the radially expanded and plastically deformed expandable members are fabricated from a steel alloy comprising a weight percentage of

carbon of less than about 0.20% and a charpy V-notch impact toughness of at least about 6 joules.

45. A method for manufacturing an expandable member used to complete a structure by radially expanding and plastically deforming the expandable member, comprising:

forming the expandable member from a steel alloy comprising the following ranges of weight percentages:

C, from about 0.002 to about 0.08;

Si, from about 0.009 to about 0.30;

Mn, from about 0.10 to about 1.92;

P, from about 0.004 to about 0.07;

S, from about 0.0008 to about 0.006;

Al, up to about 0.04;

N, up to about 0.01;

Cu, up to about 0.3;

Cr, up to about 0.5;

Ni, up to about 18;

Nb, up to about 0.12;

Ti, up to about 0.6;

Co, up to about 9; and

Mo, up to about 5.

46. An expandable member for use in completing a structure by radially expanding and plastically deforming the expandable member, comprising:

a steel alloy comprising the following ranges of weight percentages:

C, from about 0.002 to about 0.08;

Si, from about 0.009 to about 0.30;

Mn, from about 0.10 to about 1.92;

P, from about 0.004 to about 0.07;

S, from about 0.0008 to about 0.006;

Al, up to about 0.04;

N, up to about 0.01;

Cu, up to about 0.3;

Cr, up to about 0.5;

Ni, up to about 18;

Nb, up to about 0.12;
Ti, up to about 0.6;
Co, up to about 9; and
Mo, up to about 5.

47. A structural completion, comprising:
one or more radially expanded and plastically deformed expandable members;
wherein one or more of the radially expanded and plastically deformed expandable members are fabricated from a steel alloy comprising the following ranges of weight percentages:
C, from about 0.002 to about 0.08;
Si, from about 0.009 to about 0.30;
Mn, from about 0.10 to about 1.92;
P, from about 0.004 to about 0.07;
S, from about 0.0008 to about 0.006;
Al, up to about 0.04;
N, up to about 0.01;
Cu, up to about 0.3;
Cr, up to about 0.5;
Ni, up to about 18;
Nb, up to about 0.12;
Ti, up to about 0.6;
Co, up to about 9; and
Mo, up to about 5.

48. A method for manufacturing an expandable tubular member used to complete a structure by radially expanding and plastically deforming the expandable member, comprising:
forming the expandable tubular member with a ratio of the of an outside diameter of the expandable tubular member to a wall thickness of the expandable tubular member ranging from about 12 to 22.

49. An expandable member for use in completing a structure by radially expanding and plastically deforming the expandable member, comprising:

an expandable tubular member with a ratio of the of an outside diameter of the expandable tubular member to a wall thickness of the expandable tubular member ranging from about 12 to 22.

50. A structural completion, comprising:
one or more radially expanded and plastically deformed expandable members positioned within the structure;
wherein one or more of the radially expanded and plastically deformed expandable members are fabricated from an expandable tubular member with a ratio of the of an outside diameter of the expandable tubular member to a wall thickness of the expandable tubular member ranging from about 12 to 22.

51. A method of constructing a structure, comprising:
radially expanding and plastically deforming an expandable member;
wherein an outer portion of the wall thickness of the radially expanded and plastically deformed expandable member comprises tensile residual stresses.

52. A structural completion, comprising:
one or more radially expanded and plastically deformed expandable members;
wherein an outer portion of the wall thickness of one or more of the radially expanded and plastically deformed expandable members comprises tensile residual stresses.

53. A method of constructing a structure using an expandable tubular member, comprising:
strain aging the expandable member; and
then radially expanding and plastically deforming the expandable member.

54. A method for manufacturing a tubular member used to complete a wellbore by radially expanding the tubular member at a downhole location in the wellbore comprising: forming a steel alloy comprising a concentration of carbon between approximately 0.002% and 0.08% by weight of the steel alloy.

55. The method of claim 54, further comprising forming the steel alloy with a concentration of niobium comprising between approximately 0.015% and 0.12% by weight of the steel alloy.

56. The method of claim 54, further comprising: forming the steel alloy with low concentrations of niobium and titanium; and limiting the total concentration of niobium and titanium to less than approximately 0.6% by weight of the steel alloy.

57. An expandable tubular member fabricated from a steel alloy having a concentration of carbon between approximately 0.002% and 0.08% by weight of the steel alloy.

58. A method for manufacturing an expandable tubular member used to complete a wellbore completion within a wellbore that traverses a subterranean formation by radially expanding and plastically deforming the expandable tubular member within the wellbore, comprising:

forming the expandable tubular member from a steel alloy comprising a charpy energy of at least about 90 ft-lbs;

forming the expandable member from a steel alloy comprising a charpy V-notch impact toughness of at least about 6 joules;

forming the expandable member from a steel alloy comprising the following ranges of weight percentages:

C, from about 0.002 to about 0.08;
Si, from about 0.009 to about 0.30;
Mn, from about 0.10 to about 1.92;
P, from about 0.004 to about 0.07;
S, from about 0.0008 to about 0.006;
Al, up to about 0.04;
N, up to about 0.01;
Cu, up to about 0.3;
Cr, up to about 0.5;
Ni, up to about 18;
Nb, up to about 0.12;
Ti, up to about 0.6;
Co, up to about 9; and
Mo, up to about 5;

forming the expandable tubular member with a ratio of the of an outside diameter of the expandable tubular member to a wall thickness of the expandable tubular member ranging from about 12 to 22; and

strain aging the expandable tubular member prior to the radial expansion and plastic deformation of the expandable tubular member within the wellbore.

59. An expandable tubular member for use in completing a wellbore completion within a wellbore that traverses a subterranean formation by radially expanding and plastically deforming the expandable tubular member within the wellbore, comprising:

a steel alloy having a charpy energy of at least about 90 ft-lbs;

a steel alloy having a charpy V-notch impact toughness of at least about 6 joules; and

a steel alloy comprising the following ranges of weight percentages:

C, from about 0.002 to about 0.08;

Si, from about 0.009 to about 0.30;

Mn, from about 0.10 to about 1.92;

P, from about 0.004 to about 0.07;

S, from about 0.0008 to about 0.006;

Al, up to about 0.04;

N, up to about 0.01;

Cu, up to about 0.3;

Cr, up to about 0.5;

Ni, up to about 18;

Nb, up to about 0.12;

Ti, up to about 0.6;

Co, up to about 9; and

Mo, up to about 5;

wherein a ratio of the of an outside diameter of the expandable tubular member to a wall thickness of the expandable tubular member ranging from about 12 to 22; and

wherein the expandable tubular member is strain aged prior to the radial expansion and plastic deformation of the expandable tubular member within the wellbore.

60. A wellbore completion positioned within a wellbore that traverses a subterranean formation, comprising:

one or more radially expanded and plastically deformed expandable tubular members positioned within the wellbore completion;

wherein one or more of the radially expanded and plastically deformed expandable tubular members are fabricated from:

a steel alloy comprising a charpy energy of at least about 90 ft-lbs;

a steel alloy comprising a charpy V-notch impact toughness of at least about 6 joules; and

a steel alloy comprising the following ranges of weight percentages:

C, from about 0.002 to about 0.08;

Si, from about 0.009 to about 0.30;

Mn, from about 0.10 to about 1.92;

P, from about 0.004 to about 0.07;

S, from about 0.0008 to about 0.006;

Al, up to about 0.04;

N, up to about 0.01;

Cu, up to about 0.3;

Cr, up to about 0.5;

Ni, up to about 18;

Nb, up to about 0.12;

Ti, up to about 0.6;

Co, up to about 9; and

Mo, up to about 5;

wherein at least one of the expandable members comprises a ratio of the of an outside diameter of the expandable member to a wall thickness of the expandable member ranging from about 12 to 22;

wherein an outer portion of the wall thickness of at least one of the radially expanded and plastically deformed expandable comprises tensile residual stresses; and

wherein at least one of the expandable tubular member is strain aged prior to the radial expansion and plastic deformation of the expandable tubular member within the wellbore.

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INVESTOR IN PEOPLE

**Application No:** GB0505039.8 **Examiner:** Mike Walker

**Claims searched:** 1, 4, 8, 11 **Date of search:** 22 July 2005

## Patents Act 1977: Search Report under Section 17

**Documents considered to be relevant:**

| Category | Relevant to claims | Identity of document and passage or figure of particular relevance |
|---|---|---|
| X | 1 to 13 | WO2004/027392 A1 (ENVENTURE) whole document incl. claims 1 to 7 |

Categories:

| | | | |
|---|---|---|---|
| X | Document indicating lack of novelty or inventive step | A | Document indicating technological background and/or state of the art. |
| Y | Document indicating lack of inventive step if combined with one or more other documents of same category | P | Document published on or after the declared priority date but before the filing date of this invention. |
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**Field of Search:**

Search of GB, EP, WO & US patent documents classified in the following areas of the UKC$^{X}$ :

| |
|---|
| G1S |

Worldwide search of patent documents classified in the following areas of the IPC$^{07}$

| |
|---|
| G01N |

The following online and other databases have been used in the preparation of this search report

| |
|---|
| EPODOC, WPI |